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RELATIONS OF IRRIGATION TO GEOGRAPHY.

A LECTURE BY

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The relation between Irrigation and Geography seems at first so distant as to render it scarcely evident why a geographic society should be addressed on a purely engineering and agricultural subject. Until within the last decade the half of our great West, a third of the United States, was almost devoid of men and the works of man, outside of limited and widely separated areas in the mountains, where the pursuit of mining flourished. The plains and deserts were uninhabited but for the scattered herds of the ranchman.

All this is rapidly changing; villages are springing up in the desert; the centres of population are moving from the mountains to the plains; numerous roads traverse what was but recently the so-called Great American Desert. Railways and, best of all, canals of life-giving water thread the plains in various directions. All this because we have discovered that where before we had the land, and far from it in the mountains the water, the union of these can transform the former, even in its most forbidding aspects, into a veritable garden spot. Irrigation will, in the next century, entirely change the geography of the great West, and many of the blank spaces on the map will be more densely covered with village names than are similar areas in our East. It seems but proper, therefore, that a geographical society should know something of the art which is producing such stupendous results.

The word "irrigation" may imply to you a condition far more imposing than is intended. In dry weather your neighbor takes a watering pot and sprinkles such of his plants and flowers as he con-

siders most valuable, while, perhaps, with the hose or water barrel he moistens more or less of his garden truck. This is irrigation pure and simple. The only difference between this form and that more generally implied by the word irrigation as used in the arid West is, that in the latter region the application of water to the crops becomes a business by itself, and the farmer and the engineer unite in studying out methods whereby water may be applied in the easiest, least expensive and most certain manner. This is by aid of the action of gravity, and irrigation by natural flow is the result. Ditches are made which lead the water from the source of supply, be it well, reservoir or stream, and they are so aligned and graded that the water shall flow through these and from them into minor channels, and from these again it is led by ploughed or drilled furrows through the cultivated fields.

The mistake is too commonly made of regarding the work of irrigation as a hardship, and the necessity for it as a misfortune. In point of fact the necessity for irrigation and the ability to irrigate make a fortunate combination of circumstances for the agriculturist. The necessity for irrigation implies a warm, dry climate, as that of the arid regions, and this means that the crops are not liable to destruction by sudden, violent storms, nor by the lack of sufficient sunshine, nor by the failure of water supply as sometimes results from dependence upon rainfall. These are the conditions which prevail in the West. All of this fortunate combination of circumstances is not found in the semi-humid region, where the rainfall is usually sufficient, and there is, therefore, not the ever-present sunshine and the immunity from damaging storms; yet here irrigation may fulfil one of its most important functions, that of helping nature over the drought periods.

Even where irrigation is not essential to the production of crops, as in the Central and Southern States, there come occasional years of drought when crops which give promise of the most abundant yield are suddenly injured by an unusual period of dry weather. At such times had the farmer the power to supply the moisture which nature has failed to give, he would be able to tide his crop over the dry period and thus to protect himself against an almost certain loss. Irrigation may thus be regarded as a form of insurance. Every business man insures the contents of his store; why should it not be equally profitable for the man who depends upon the product of the soil, which in itself is dependent upon the moisture supplied it, to put an insurance policy on his crops? The farmer's house or his barn are probably far less frequently destroyed by fire

than are his crops by drought, and yet the loss in the latter case is even more serious than in the former.

For convenience in referring to the lands of the country in irrigation parlance, those of the extreme West are usually called "arid," those between theMississippi Valley and the Rocky Mountains, where the rainfall is nearly sufficient to insure the crops, are spoken of as "semi-humid," and the lands to the east of these are usually referred to as "humid," being those on which the rainfall is sufficient for the protection of crops. Yet this distinction is, to a certain extent, arbitrary, as it depends largely upon the amount of mean annual precipitation. The true distinction between arid and humid regions is dependent rather upon the amount of precipitation during the crop-growing season. In the humid regions in one season out of three the crops are short, the result of unfavorable climatic conditions. The farmer is, consequently, unable to get the maximum product each and every year from his land, and therefore is compelled to cultivate greater areas than he is really able to handle to the best advantage.

Where, as in the arid West, there is an abundance of good soil and plenty of sunshine, and the farmer can apply water just when and as he will, the tilling of the soil becomes a science. It is possible to learn precisely the amount of water required for different crops, and accordingly to produce the maximum output from the minimum areas. As a result, where irrigation is most successfully practised, as in Utah and southern California, the farms are of the smallest size. The average area of an irrigated farm in the State of Utah is twenty-three acres. The average size of a California farm is seventy-three acres, yet the majority of farms in southern California range in cultivated crops only from ten to thirty acres in extent. From such small areas as these farmers are able to produce such abundant yields as to enable them to live with an ease and comfort not known among the smaller farmers of our Eastern States. Another advantage gained by irrigation is in the ability to diversify crops. This is a matter of greatest importance in the Southwest, where the farmers are able to produce but few crops; had they the assurance of sufficient water supply at the time when vitally needed, they might cultivate many of the more valuable fruits and vegetables which are not now found profitable.

Irrigation is not only practised in the arid and semi-humid regions; it is extensively employed in regions of considerable rainfall. In Italy there are about 3,700,000 acres of irrigated lands, and in France a half million of acres. In these countries the annual rain-

fall is nearly as great as in the Eastern States. While the precipitation is ample in Italy and France for the production of ordinary crops, irrigation is practised to increase the yield and offset the consequences of drought. The general impression that irrigation is useful only in arid countries is entirely erroneous. It is such regions as the semi-arid plains of Kansas, Nebraska, Oklahoma and eastern Texas, which are especially in need of irrigation. Here occur usually a series of wet seasons when the rainfall is sufficient to produce abundant crops. At such times immigration is at its maximum, settlement is rapid, and buildings and fences are erected, and the farmers spend their all, as well as mortgage their property, in the hope of gaining a livelihood. Then comes the period of drought. One or two successive seasons of half crops render the inhabitants destitute; they lack the means to pay their debts or purchase food, and were it not for our magnificent transportation facilities and the charity of our people, most woeful famines would devastate these countries. The consequences of drought in the East are not so serious, yet their effect is to render the farmer less prosperous and his life a harder and more laborious one than if he were protected by irrigation.

The history of agriculture by irrigation is as old as the history of the world. History begins in the Valley of the Nile, yet that valley has been irrigated since earliest times. The first agriculture in Europe, Asia and Africa began in arid regions, where irrigation was practised as an essential. In our own country the early Spanish explorers discovered the remains of irrigation works, showing that agriculture by this means was practised by the Aztecs. The remains of their canals and irrigation ditches are to be seen still, in a fair state of preservation, in many parts of the Southwest. The earlier American irrigation works were designed in a haphazard manner by county surveyors, or by railway engineers who possessed little knowledge of the principles of hydraulics underlying the subjects with which they were dealing. Recently the practice of irrigation has developed into a special science, and there has gradually grown up a vast amount of information regarding the branches of engineering most nearly allied to irrigation. As a separate branch of engineering, irrigation first received recognition in India, where a corps of irrigation engineers was first organized about forty years ago, at the time when the British Crown assumed control of that country.

According to the Census Reports the average size of irrigated farms in the United States is sixty-eight acres, and the average

value of the product per acre in 1889 was a little less than $15. This gives no real index to the actual value of some of the crops which are produced by irrigation. Farming with the aid of irrigation is more lucrative—though more expensive—than farming without it. The first cost of land without water supply depends upon the locality. It ranges from $1.25 per acre to from $10 to $25 per acre where the crops and lands are more valuable, as in limited portions of Colorado, Utah and California. The average cost per acre of developing an irrigation plant ranges from $4 in Idaho and Montana, to $10 and $15 in Utah, Colorado and California. The average annual cost of supplying water, per acre, in other words, the average water rental paid by the farmer, ranges from 75 cents to $2, though it is much more expensive than this in some portions of southern California. To these costs must be added those of preparing the land for cultivation, such as clearing, fencing and ditching it. Yet in spite of this apparently large outlay—$5 for land, $10 for irrigation plant, and $2 per annum water rate—lands so made irrigable are at once valued at anywhere from $30 to $100 per acre, while their annual output is frequently as great as these figures. Thus we find that the average annual value of the products per acre of irrigated lands ranges from $15 in the Northwestern States, to $25 or $30 per acre in Utah or Colorado, and up to $500 per acre in California. In the latter region peach, apricot and prune orchards frequently return $100 to $150 per acre. The yield of raisin grapes is often worth from $200 to $250, and of oranges and olives from $300 to $500 per acre.

Let us now examine more carefully the parts which go to make up an irrigation system. Beginning with the rainfall from which the water supply is derived; the mountains in which it is conserved in lakes and gathered in streams to feed the canals; the reservoirs in which it is sometimes necessary to store it; and the main canals which conduct these waters to the irrigable lands; we will then glance at the methods of applying the waters to the soil, at the lands available for irrigation, and at the crops which result from this union.

The true index to the amount of precipitation available for irrigation is not the actual recorded precipitation, but the percentage of this which flows off into the streams and which is known as "run-off." This quantity differs in various portions of the country with the slopes, the flora, the temperature and the soil. A glance at a run-off map of the United States shows in the darker shade of color that portion in which the run-off exceeds 20 inches in depth. This,

it will be observed, is in the eastern and southern portions of the country, in the Cascade regions of Washington and Oregon and in limited areas in the Rocky Mountains. There irrigation is unnecessary because the quantity and distribution of precipitation is sufficient to mature crops. Throughout the desert regions of Arizona, Utah, Nevada, Oregon and Idaho, and in portions of western Kansas, Nebraska and Texas, the run-off is less than two inches. There, not only is precipitation too small to mature crops, but the amount of run-off is too small to furnish supplies for irrigation. The major supplies for irrigation waters in the arid regions are to be derived, as shown by the run-off map, from the great mountains of the Pacific Coast and from the Rocky Mountains in Colorado, Wyoming and Montana, as well as from limited areas in others of the Western States.

One of the best typical irrigation basins of the arid West is that including the drainage of the Arkansas River in Colorado. Your attention is called to it because it illustrates well how use may be made of all the waters of a drainage basin for the irrigation of its agricultural lands. The Arkansas River rises among great mountain peaks, ranging from 12,000 to 14,000 feet in height, capped with perpetual snow. The lower foothill slopes to the east of the mountains are irregular in shape, covered with a scattered growth of scrubby timber, and furnish excellent grazing for cattle. Among these foothills are numerous sites suitable for the construction of reservoirs, in which to store the surplus water that comes from the higher mountains and retain it until needed for irrigation during the cropping season. To the eastward of the foothills is a great area of gently rolling land, well suited for the raising of all crops which will grow in the climate of Colorado. Through this the Arkansas and its tributaries have eroded deep channels, and it is therefore necessary in order to conduct the irrigation waters to the lands above these, to divert the waters of the river by canals heading in the foothills and lead them on suitable gradients to the plains below.

If we observe the character of the higher mountains, on which the rainfall is great and which furnish the ultimate source of supply of irrigation waters, the steepness of the barren rocky slopes shows clearly that the greater percentage of the precipitation in such a region runs off to the streams, as it would have no opportunity to lie quietly and evaporate, or percolate into the ground. The little streams which gather the water in these mountains connect together in rushing mountain brooks flowing over steep and

pebbly beds, and these emerge from the mountains on to the foot hill slopes in broad and shallow rivers, the waters of which, if not diverted into canals for irrigation at these points, quickly sink into the ground or are evaporated, leaving the river beds practically dry but a few miles further on. An examination of a diagram showing the discharge of such a river, the Arkansas for example, gives an idea of the irregularity of its flow. From January to April its volume is practically uniform, as it is from August to December, the discharge being approximately 500 cubic feet per second, but between May and August, the period in which the snows are melting in the mountains under the influence of warm rains, the volume of the river rapidly rises to a maximum at the end of June of 4,500 cubic feet per second, nine times that which it normally has. It is this great volume of water which it is desirable to conserve in storage reservoirs, otherwise it rushes off in floods to the ocean and is lost to irrigation. It is to preserve this water until it is wanted by irrigators that storage reservoirs are built.

On the flat plains country to the east of the Rocky Mountains, in Kansas, Oklahoma, etc., the occasional precipitation either sinks into the soil and is thus lost to agriculture, or it occurs in violent storms of short duration and rushes as a flood over the entire surface of the land, falling into the streamways over steep banks which are eroded by its action. At times the volume of this surface run-off is so great as to produce temporary waterfalls of giant proportions, and it can be readily realized that such falls rapidly wash away the banks of the ordinarily dry streams.

Let us glance now at the character of the irrigable lands. In western Kansas, Nebraska and Texas we find a flat prairie land which produces an abundant natural growth of grass, but here the rainfall is insufficient or is so poorly distributed as to make agricultural pursuits hazardous without the aid of irrigation. Here the soil is deep and fertile, water alone being required to make it productive. In New Mexico we find rolling plains, the slopes covered with short bunch grass, juniper bushes and sage brush, the surface practically barren of vegetation and exposing a sandy or loamy, barren soil. This is among the most fertile of the soils of our country when water is applied to it, and is capable of producing the finest varieties of all valuable fruits and vegetables. In Arizona, Utah, Idaho and Nevada, the best agricultural lands are the great level, sandy and barren plains covered with occasional scattered bunches of sage brush. Here rainfall is entirely inadequate to the maturing of crops, but when artificially watered this soil is equally

as productive as that found in other portions of the arid regions. An idea of the fertility of this soil may be readily gained by a glance at some of the thickets of cacti which flourish in all the southern portions of this region, plants which mature in the most barren country and without rain or other watering.

In addition to the surface water supplies, those derived from run-off from streams or conserved in storage reservoirs, there are large volumes of sub-surface water ; water which has filtered or percolated into the ground, whence it may be got by digging wells or boring artesian wells. In the West are some great artesian basins, notably those of the Dakotas and Texas; the Carson Valley of Nevada, and the valleys of southern California. Here numerous artesian wells are bored and furnish such volumes of water as provide for the irrigation of considerable areas of land. As these wells flow continuously, while irrigation is practised intermittently, it is therefore found advantageous to build about them storage tanks or reservoirs in which the water may be conserved or collected until wanted in irrigation. Some of these storage reservoirs are made most beautiful, especially in southern California, by planting about them palms, lilies and other tropical plants which flourish luxuriantly under the genial sunshine of that clime and the beneficent moisture of the artesian waters. Others of these reservoirs are quite extensive and are supplied by large wells, or numbers of wells, and have been so beautified and arranged as to produce picturesque lakes.

Irrigation, as originally practised in Asiatic countries, consisted chiefly in pumping water out of wells and pouring it into small ditches which carried it to the irrigated fields, or more expeditiously in bailing it, as it is called, by two men swinging a wicker basket between them in such a manner as to toss the water from the stream into the irrigating ditch. Again, it is raised from wells by the "shadoof" or "pakota," which is simply our old-fashioned well-sweep, several of these being sometimes arranged in a series of steps one above the other, the water being lifted from the lower level and emptied into a trough above, whence it is raised by the next higher well-sweep through a further elevation until it ultimately reaches the ditches which conduct it to the fields.

Pumping is also practised in our own country, especially in the plains region, where there is a constant and regular wind supply, and well water or water from shallow streams is raised by various forms of windmills. Sometimes by the old-fashioned windmill, which lifts the water from its lower level into ditches which flow above the surface. More commonly we find modern windmills, and

these are provided with storage reservoirs as are artesian wells, so that the mill may be run whenever the wind suffices, and store up water for use when wanted in irrigation. Again, on flowing streams water wheels are employed to pump a portion of the volume used in producing their power to higher levels for irrigation. Still again, steam pumps, not infrequently of large size, lift water continuously to storage reservoirs, whence it is conducted to the irrigated fields.

And now we turn to the main sources of supply for irrigation, the surface waters. In the mountains, that volume of water which flows off during flood seasons is caught in great reservoirs or artificial lakes where it is stored until required for irrigation, and then it is liberated and flows for many miles down the mountain streams until it reaches the neighborhood of the irrigable lands, where it is diverted in ditches. A glance at one of the localities in which such reservoirs are constructed gives us an idea of the kind of mountain valley best suited to their uses. A great dam is built across the confining hill slopes at the foot of the valley, thus forming an artificial lake which will store large volumes of flood water. The building of such a mountain dam is an interesting process. It may be constructed of earth or of substantial masonry, or, as is not uncommon in the higher and less accessible mountain region where labor and transportation are expensive, a cribwork is constructed of logs, cut in the immediate neighborhood and weighted down with heavy rocks to hold them in place. One of the most magnificent and substantial storage reservoirs in the West is that formed by the Sweetwater dam in southern California, a massive masonry structure which bars the rocky outlet of a broad valley. Great care and skill must be exercised in constructing such a dam, for be the engineer's calculations of flood volume ever so liberal, a flood may occur of such volume as to fill the reservoir and top the dam, as in the case of the Sweetwater dam, but fortunately without causing its rupture. In building a masonry dam to withstand such hydraulic forces the foundations must be dug deep and well, so that the masonry may rest on the most substantial and homogeneous rock, far below the natural surface of the ground.

The waters stored in these mountain valleys are conducted sometimes directly by ditches to the irrigable lands, at other times are passed back into streams and again diverted therefrom lower down. In the valley of the Arkansas in Colorado are numerous irrigating ditches diverted from that stream. Some of the flood waters of the stream are conserved in the mountains in reservoirs, whence they are liberated when needed, and flow for many

miles down the Arkansas to the neighborhood of Pueblo, where the stream leaves the mountains. From there on down the stream numerous ditches are diverted, which climb in long and tortuous curves away from the river banks until they reach the upper and more level plains lands. From these ditches are then taken other and smaller channels which irrigate the fields, or, not uncommonly, they discharge much of their volume into reservoirs constructed on the plains lands where it is stored until it is wanted for irrigation; so that a double system of storage is practised, that of the mountain waters which are retained in time of flood, that from ditches which are permitted to run full at all times of the year, though the waters which they carry are utilized but occasionally during the summer. The plains reservoirs are often quite numerous, dotting the uplands in all directions. They are natural hollows or lakes on the plains, ordinarily dry or filled with alkali water, but when utilized as reservoirs filled with good, fresh, river water. A cheap earth dam is constructed at the outlet of these, supplemented by a cut which reaches to the level of the bed, and thus enables a large volume to be retained within them and allows this to be easily withdrawn. Some of the plains reservoirs are quite picturesque, forming pretty lakes in the landscape, and often they are of such dimensions as to be utilized as fish ponds and enjoyed by pleasure seekers in row and sail boats.

The waters which flow through the great rivers of the plains can only be diverted from these by means of great ditches, weirs and dams of expensive and difficult construction, built to withstand the eroding action of the immense volumes of water which assail them. The Arizona dam, on the Salt River in Arizona, has had to withstand the erosive action of floods greater than the discharge of the Potomac or Hudson or even that of the Mississippi River, yet in ordinary seasons the discharge from this stream is so small as to scarcely fill the canals which are diverted from it. These dams are usually built at the points at which the streams debouch from the hills to the plains. At one end of such a dam heads the supply canal, which is usually constructed at great expense by difficult excavation in the rocky slopes of the mountains, until it finally emerges from their confining walls and finds its way by winding curves through the irrigable lands of the plains. In order to control the admission of the river water into the canals at the point of stoppage of its flow by the dam, there must be built in the head of the canal great regulating works or gates, which may be lowered or raised according to the amount of water which it is desirable to

permit to enter the canal. An excellent example of the relation of the head gates to the canal, the supplying stream and the dam, is that furnished by the Folsom canal, diverted from the American River in California.

The diversion line, as it is called, of some of these canals—by which is meant that upper portion of its line which is built merely to get the water from the river to irrigable lands, and not that portion which is doing active work in irrigating the fields—is usually the most difficult and expensive portion of the canal to build, as it has to cut through rocky slopes, tunnel ridges and be carried across ravines in flumes or pipes. The construction of such canals is an interesting and expensive operation according to its size. It may be so small that the excavation can be made by hand. In California not uncommonly the hydraulic monitor is employed in excavating the canal line and water itself is utilized in digging the channel through which water is later to flow. One of the greatest canals in the country, the New York Canal in Idaho, was constructed rapidly and with a large force of men, working with modern tools, ploughs, scrapers and excavators. In flat valley country, as in the Sacramento valley in California, canals have been simply and cheaply constructed by great steam dredging machines, the work being executed on a scale commensurate with its magnitude.

Some of the cuts which must be made in excavating these canals are deep and difficult, as that on the Payette canal in Idaho. Again, the water is conducted around rocky slopes in wooden flumes built against the rock walls; at other times, that its grade may be maintained, it is carried across creeks and ravines in similar flumes, and even after it reaches the level and more gently sloping irrigable lands it has to be carried across side drainage lines in flumes of similar construction. The building of such flumes is a work of no mean magnitude. even when they are made throughout of wooden timbers, as is the more common practice; while others have been most substantially constructed, as those of the Santa Ana Canal, not of wood but of iron, resting on iron piers, the iron or steel framing being lined with wood. In India, where are to be found the greatest of all irrigation works, these have usually, in accordance with British methods, been built in the most substantial manner, the flumes or aqueducts being of massive masonry. The largest of these in the world is that in which the Ganges Canal is carried across the Solani River; the canal at this point being 270 feet in width on top and ten feet in depth, a stream which far exceeds in magnitude the Erie canal and in fact many of the rivers of our country.

Instead of in flumes, water is sometimes carried across ravines in what are called "inverted siphons," or more properly "pressure pipes," which are wooden pipes constructed much like a continuous barrel, bound with iron hoops, and through these the water flows down the hill-slopes on one side and up the other; the down-stream end being necessarily lower than the upper or inlet end that the pressure from the latter may be sufficient to force the water through the pipe. Again, the line of these diversion canals may be blocked by ridges which must be tunneled, and in some cases there occur, as on the Bear River Canal in Utah, two or three such tunnels following each other in quick succession.

Finally, the diversion line emerges from the confining hills, and the canal is now a broad and limpid stream, well graded, which meanders slowly through the gently undulating plains which are to be irrigated. Sometimes the slopes are so even that the canal may be carried as a direct line, a beautiful, straight, silver stream, through the immense valley. In the banks of such canals are built, at occasional intervals, gates of wood or masonry, through which the water can be passed into smaller or minor canals and ditches which lead it to the irrigable fields, and from these it is discharged into still smaller channels which distribute it over the land. Some of these smaller irrigating ditches are excavated at considerable expense, and those taken from the larger canals are often works of quite as great magnitude as the main canals taken from smaller streams. As these canals pass through the plains, it not infrequently happens that the slopes of the plain are greater than the permissible slopes of the canal, for if the slope of the canal were too great it would erode its banks; there are, therefore, at intervals in these canals, falls by which the water is lowered with a single drop from one level to another, and it is usually just above such falls that the branch canals are diverted. In southern California, where water is more valuable than in the plains region, because of its scarcity and the value of the crops it produces, it is not allowed to flow through channels excavated in the earth, as much of its volume would be dissipated by percolation into the ground and by evaporation from the surface. Here it is conducted through narrow and deep channels lined with masonry to prevent its loss.

Ultimately these minor ditches reach the fields, and there the water is again checked by regulating gates which turn it in greater or less volume, as may be desired, into the slightly smaller channels from which it is flowed over the land. The processes of irrigating the land from these minor channels vary according to the crop, the

soil and the slope of the land. In some portions of the West, especially in Wyoming, Montana and the mountains of Colorado, where water is comparatively abundant and the climate such that hay and grain crops can be successfully produced, water is handled wastefully by being flowed over the entire surface of the field at each irrigation. In such cases a break is made in the bank of the ditch whence the water is conducted and coaxed by the use of a hoe in such manner as to lead it in a uniform sheet over the entire meadow. After it has flowed for perhaps a day it is stopped off and permitted to soak into the soil. Two or three, perhaps four such irrigations in a season, are sufficient to produce as many heavy crops of hay. Again, instead of breaking the banks of the irrigating ditches, a more common practice is to use a "check" or "stop" of some kind in the ditch. Not infrequently a curtain of canvas, weighted with a clod of earth, is dropped into the ditch, thus forcing the water back over its banks whence it floods the grain fields.

The more effective way in which to use water in irrigating is by flowing it through drill rows or furrows, ploughed sometimes with a single cultivator, but occasionally on a larger scale with great steam gang-ploughs. In these furrows or drill rows are planted the various crops, and through them flows the water which moistens them. It is not possible to irrigate grain or hay in this way, because the rough, furrowed surface would prevent its being mowed with machinery; so that hay or grain crops, where intelligently handled, are irrigated through shallow rows made by the drilling machine which sows the seed, and these do not cause the surface of the ground to be any more irregular than they do in the East, where irrigation is not practised.

Potatoes, cabbages, corn and similar crops, however, are planted in deep-furrowed rows, made by ploughing the land with a plough the share of which is V-shaped, and does not turn the earth in one, but in both directions. Crops are planted on the intervening ridges, and through the furrows flows the irrigating fluid. Fruit crops are sometimes irrigated by running several rows of shallow furrows between the trees; through these pass small streams of water which, flowing rapidly, percolate well into the ground and moisten the roots of the trees from a distance, and deeply, thus producing the most desirable effect, that nearly approaching a steady moistening by a soaking rain. A less satisfactory, but quite common way of irrigating trees, is by running a couple of ditches, one on either side of the trees and nearer to them, and from these the water seeps into the ground and about the roots. On steep

hillsides the ground is levelled off in terraces, as in the foothills of California, and the water is flowed through ditches on the upper terrace, settling in basins constructed about each tree, and when these basins are full and the water has stood in them long enough to soak the ground it is drawn off into the next terrace and series of basins below it, and so it flows on down hill, watering terrace after terrace in its progress.

The products of irrigation unquestionably exceed in amount and quality those produced under the vicissitudes of natural conditions. Sunshine is ever present, the soil chosen is always the best, water is applied just when wanted, and the result is to bring about practically such conditions as exist in a hothouse or conservatory. Such a crop of potatoes as is ordinarily gathered in the irrigated fields of the arid West cannot be harvested in the humid East. The cabbage crops of the same region are equally luxuriant and abundant. In irrigated cornfields the stalks far exceed in height and in verdure those of unirrigated regions, while an average of two or three ears of enormous size is produced on each stalk. The crop of an irrigated wheat field, where the water is intelligently handled, may, like all other irrigated crops, run to leaf or to grain, according to its treatment. Where properly handled, the leaf and stalk, in other words, straw, will be least in amount and the grain greatest.

The art of agriculture by irrigation is quite as different from the art of agriculture in humid regions, as is the act of irrigating land different from the act of cultivating without irrigation. Abundant as are the grain and vegetable crops of irrigated fields, the hay crops are equally luxuriant, but probably none flourish with such luxuriance under irrigation as do the grape and citrus fruits. I can conceive no more beautiful sight than a well-irrigated and well-laid-out vineyard, such as may be seen extending for miles in southern California; and no more attractive objects than the raisin, prune or apricot drying beds of a California farm at the close of the season.

In conclusion, a brief review of the processes of irrigation, and the wonderful transformations wrought by it, may be got from a study of a typical vineyard in Kern Valley, California. The case here chosen represents a period of four months; in March the field was ploughed and the ditch excavated; in May the vines were sprouting from the cutting, and by July they have attained full growth and are producing the first scanty crop of grapes. Thus irrigation, as by magic, gives constantly changing views, and our geographies must in part be rewritten to keep pace with the marvellous development of our great, arid West.